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CALDWELL, RICHARDS & SORENSEN, INC.

CONSULTING CIVIL ENGINEERS

20 South State Street, Suite 300
Salt Lake City, Utah 84111

December 27, 1976

Hydro Jet Services, Inc.
Box 325
Green River, Utah 84525

Subject: Soil Investigating and Reporting on Dam at Shootering, Utah
CRS Project #25-1033

Gentlemen:

Following my discussion of December 16 with Dr. Joe Olsen on the subject dam, he has made a written reply to the following items:

1. Seek clarification of the analysis required on the subject project.
2. Outline further information required for the analysis.
3. Report the results of preliminary evaluation of liquefaction susceptibility
4. Provide an estimate of the costs associated with analysis of the dam.

Dr. Olsen has reviewed the factor of safety requirements submitted by the Division of Oil, Gas and Mining of Utah State, and makes comments with reference to the following:

Slope Stability (failure of surfaces)
Sliding Wedge Analysis
Liquification (sic)(we assume LIQUEFACTION)
Total Seepage Possibility

It appears that the first two modes listed are unclear, and we quote from Dr. Olsen's letter:

"Sliding Wedge Analysis is a form of stability analysis which is performed in situations where natural or constructed boundaries suggest that probable failure surfaces are composed of linear segments. It does not appear at the present time that such an analysis is appropriate for the dam at Shootering. Slope stability analysis for circular failure surfaces, which I interpret as the first mode suggested, does appear to be required. Clarification of which stability analyses are required should be obtained before proceeding with any analysis."

Further comments regarding total seepage are as follows:

> "The requirement for analysis of failure based on total seepage possibility could suggest consideration of the effects of a high water table within the dam on the stability analyses, or the possibility of piping caused by flow through or around the dam which could cause erosion of the dam. If the second is their intent, information will have to be obtained on the materials at the base and abutments of the dam Clarification of this aspect will determine the scope of any further field investigation."

Dr. Olsen has indicated that the following will be required to carry out stability analyses:

> a. Cross-sections showing the dam, including the upstream bentonite seal and any other materials not previously tested, but which are part of the dam. Any information available concerning the properties of these materials would also be desired. These materials would include rip-rap and any filtering layers.
> b. Permeability data on all materials tested.
> c. Anticipated maximum water level in the pond and a projected filling sequence for the tails.
> d. Additional strength data. The strength parameters (both cohesion and friction angle) appear to be high for materials with the grain size characteristics reported. An alternative to obtaining and testing further samples would be to approach the analysis by evaluating minimum strength parameters for which there is adequate stability and comparing them with laboratory results. While being more costly in terms of analysis, this technique may lead to lower total cost.
> e. Permeability information on the underlying material. If insufficient data are available to establish that the surrounding materials are essentially impervious, a trip to the site would probably be a minimum requirement.

We enclose on a separate sheet his comments on liquefaction potential, and his further comments regarding liquefaction are:

> "This analysis shows that the soils as placed in the dam could be very susceptible to liquefaction. However, actual susceptibility of the dam to liquefaction failure could be virtually eliminated by adequately controlling the water level within the dam. If the water level within the dam is not low enough, a comprehensive evaluation of liquefaction would require expensive dynamic testing and engineering analysis. In all probability that testing would verify the results of the simplified analysis."

We estimate the cost of the analyses as required by Dr. Olsen to range between $1,500 and $2,500, based on the amount of work actually required. A breakdown of the estimated costs for each aspect of the work is attached. Actual costs would be based on the computer charges, engineering services extended and overhead.

Charges for services, equipment and facilities not furnished directly by Caldwell, Richards & Sorensen, Inc. and any unusual items of expense not customarily incurred in our normal operations, are computed on the basis of cost plus 10%. Note no additional drilling has been included in the cost submitted. These charges, if necessary, would be additional.

Sincerely,

CALDWELL, RICHARDS & SORENSEN, INC.

By M. H. Montgomery, P.E.

MHM:klm

Enclosures

Hydro-Jet Services
December 27, 1976
Enclosure #2

COST BREAKDOWN

Seepage Analysis	$ 440.00
Stability Analysis * (Improved strength data, circular surfaces only)	660.00
Stability Analysis * (Present strength data, circular surfaces only)	1,100.00
Stability Analysis * (Improved strength data, circular and wedge)	935.00
Stability Analysis * (Present strength data, circular and wedge)	1,650.00
Site Visit (Does not include further sampling)	385.00

* Note: Only one stability analysis option would be performed.

LIQUEFACTION POTENTIAL
Dam at Shootery

Liquefaction is a phenomena in which a soil loses strength during earthquakes and behaves as though it were a liquid and consequently experiences large deformations. It occurs only in saturated soils and is influenced by (1) soil type, (2) relative density, (3) initial confining pressure, (4) intensity of ground shaking and (5) the duration of ground shaking. Fine silty sands such as those at Shootery are the soils most susceptible to liquefaction. Comprehensive consideration of liquefaction potential, requires extensive and expensive laboratory dynamic testing. However, a simplified procedure has been developed whereby consideration of relative density and confining pressure is accomplished through Standard Penetration Test (SPT) results.

Such a procedure has been applied to the dam at Shootery using the data from the Caldwell, Richards and Sorensen report. The attached figure shows envelopes assuming the ground water level is at 5 feet and 10 feet below the ground surface together with the SPT results from Shootery. The envelopes divide the plot into three sections: liquefaction very likely, liquefaction very unlikely and an intermediate zone where liquefaction potential depends upon the soil type and the magnitude of earthquake shaking. For the poorly graded silty sands at Shootery and the zone 3 earthquake potential in Utah, the true envelope would be closest to the liquefaction unlikely zone.

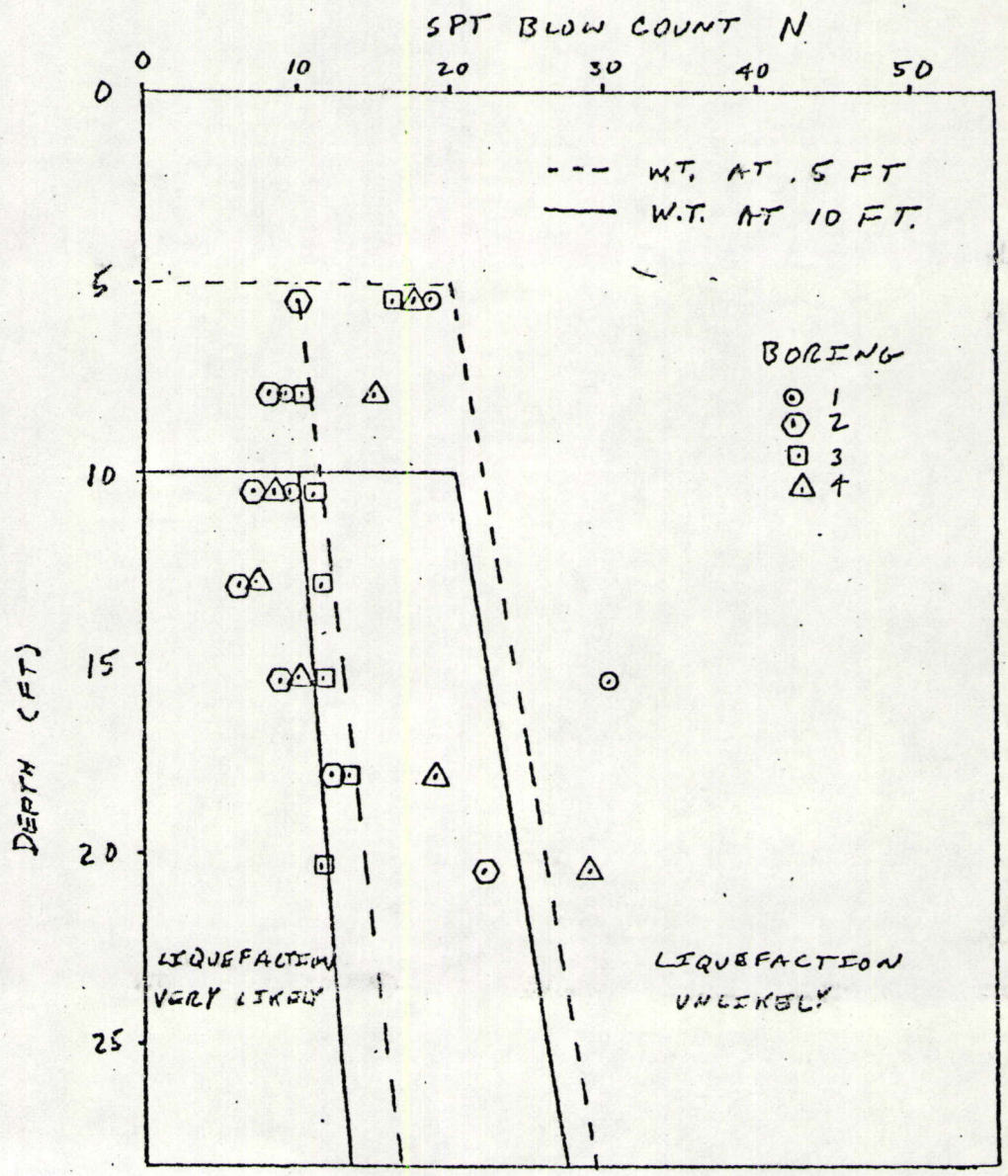
This simplified procedure indicates a high susceptibility to liquefaction with 92% of the points indicating soils likely to liquefy. Because the borings were taken at the centerline of the dam where confinement and relative density would be expected to be highest, other portions of the dam would be expected to be at least as susceptible to liquefaction.

However, susceptibility to liquefaction may be limited by keeping the free water surface low in the dam. Providing an adequate impervious barrier at the upstream face may prove adequate to eliminate the liquefaction potential.

Joseph M. Olsen
22 December 1976

SIMPLIFIED LIQUEFACTION

DAM AT SHOOTORY



J.M.O 12/76